United States Environmental Protection Agency

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Long-term assessment of ultrafine particles along major roadways in Las Vegas, Nevada and Detroit, Michigan

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Goals of this talk

- Discuss the case for making ultrafine particle (UFP) measurements in near-road areas
- Feedback on a recently developed UFP monitor designed for long-term continuous monitoring and low maintenance
- Intercomparison results of two UFP monitors
- Near-road research findings and exploratory data analysis for unique episodes, local vs. regional signals

Background

- Ultrafine particles (UFPs, diameter less than 0.1 µm or 100 nm) dominate ambient particle number count
- Traffic emissions produce significant emissions of UFP-mode particles
- Association with adverse health effects, note deposition in respiratory system (below)

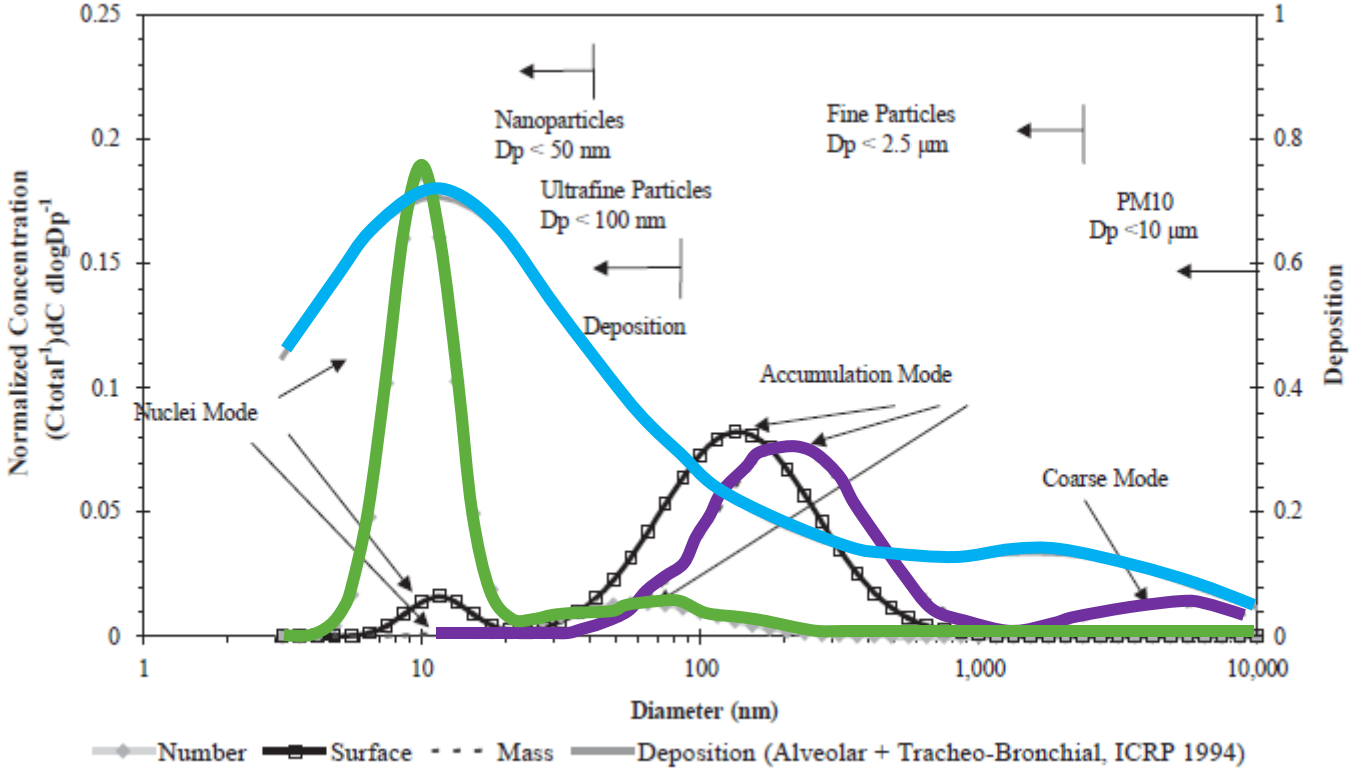


Fig. 1. Typical Diesel mass and number weighted size distributions shown with alveolar deposition.

Adopted from Kittelson et al., 2004

Background

- Major factors appearing to govern freshly emitted UFPs

Production: nucleation, condensation, coagulation

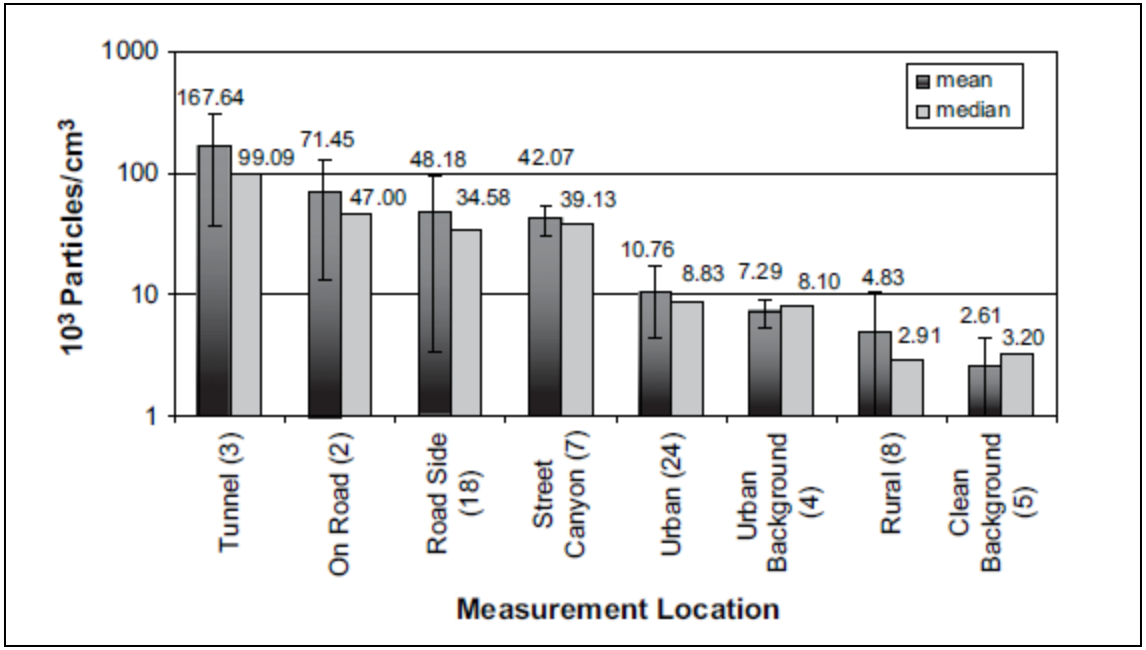
Condensational growth

Dilution: Factor of ~10,000 from tailpipe to near-road areas

Zhang et al., 2004

Background

- Significant variability in the urban environment: factor of ~5 difference from "urban background" to "roadside"

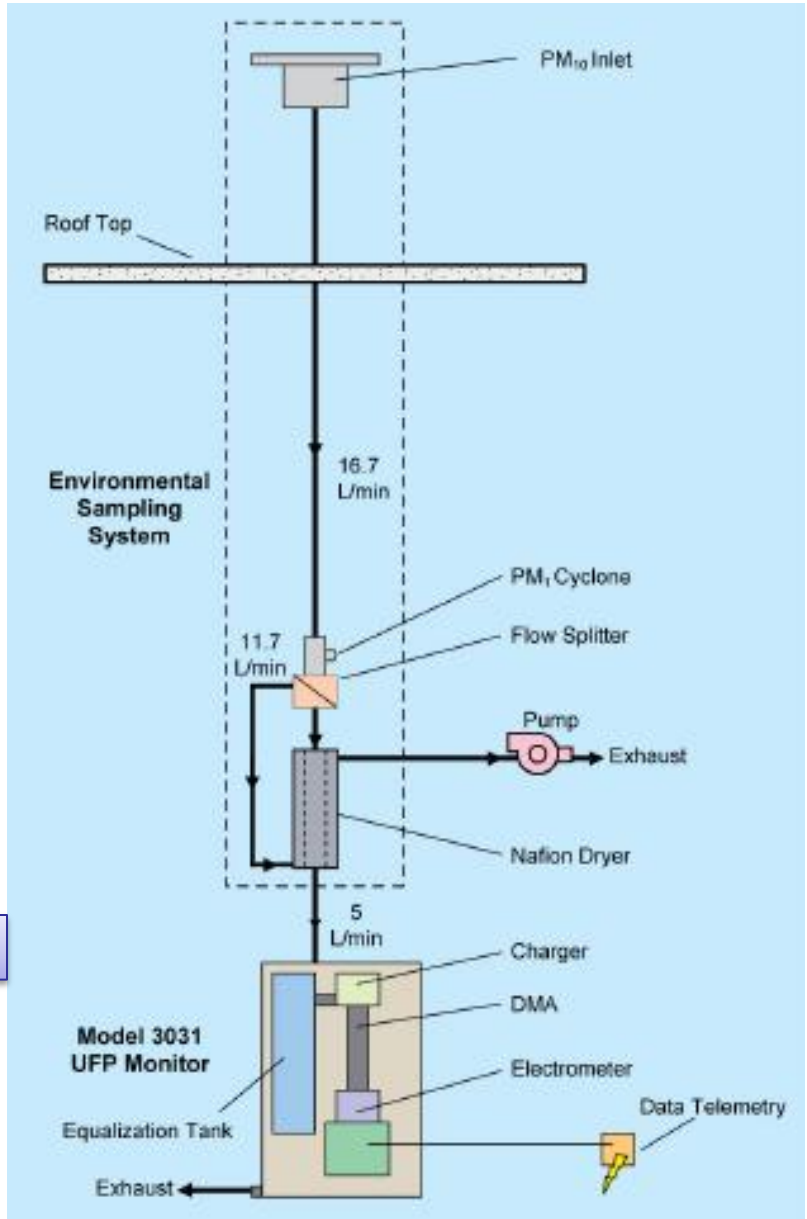


Morawska et al., 2008

Measurement focus of today:

Equipment: Ultrafine particle monitor (Model 3031, TSI, Inc.)

- Size-selects and counts particles in 6 size bins: 20-30, 30-50, 50-70, 70-100, 100-200, >200 nm
- Concentrations reported in ~15 min increments. Note: bins are sampled *sequentially*, ~2 min sample time in bin represented in 15 min data point.



Our Timeline

5/2009 — 5/2010 — 8/2010 — 6/2011 — 12/2012

Vegas near-road | *Detroit near-road* | *RTP ambient*

Long-term intercomparison

Comments on instrumentation

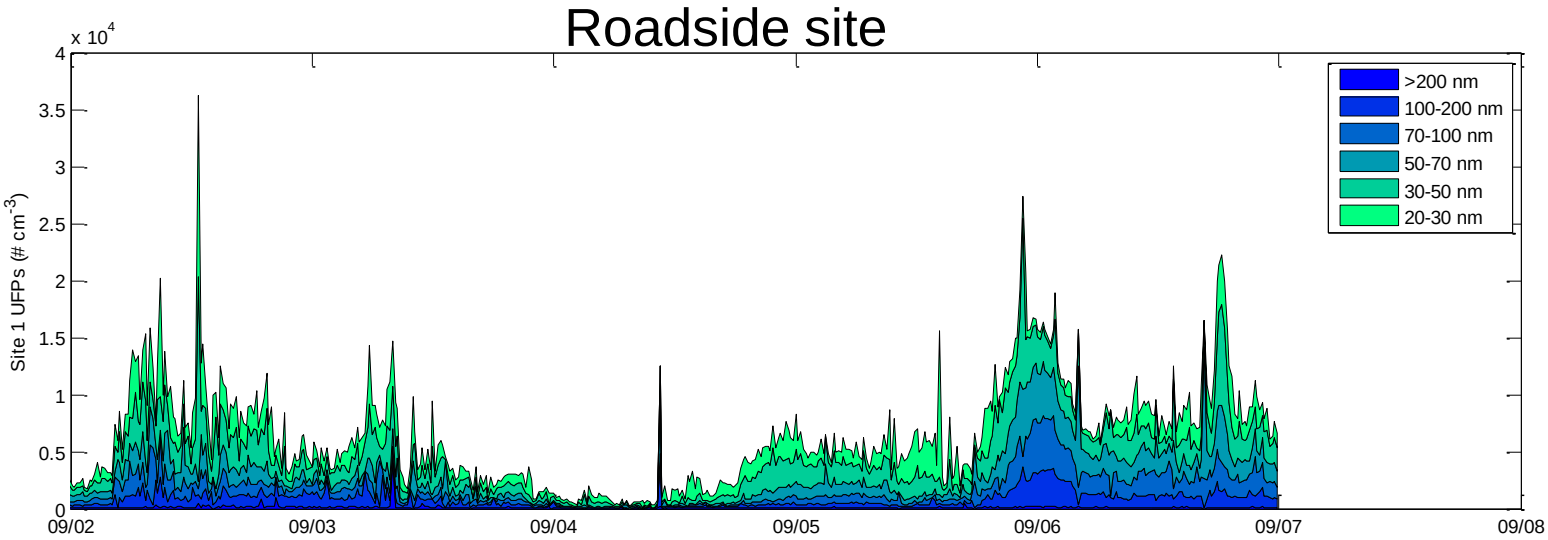
- Features we appreciate:
  - Continuous nature and time-resolution of measurements
  - Low maintenance required from sampler – no consumables, only periodic maintenance required.
  - Remote web-accessibility to view instrument performance and download data.

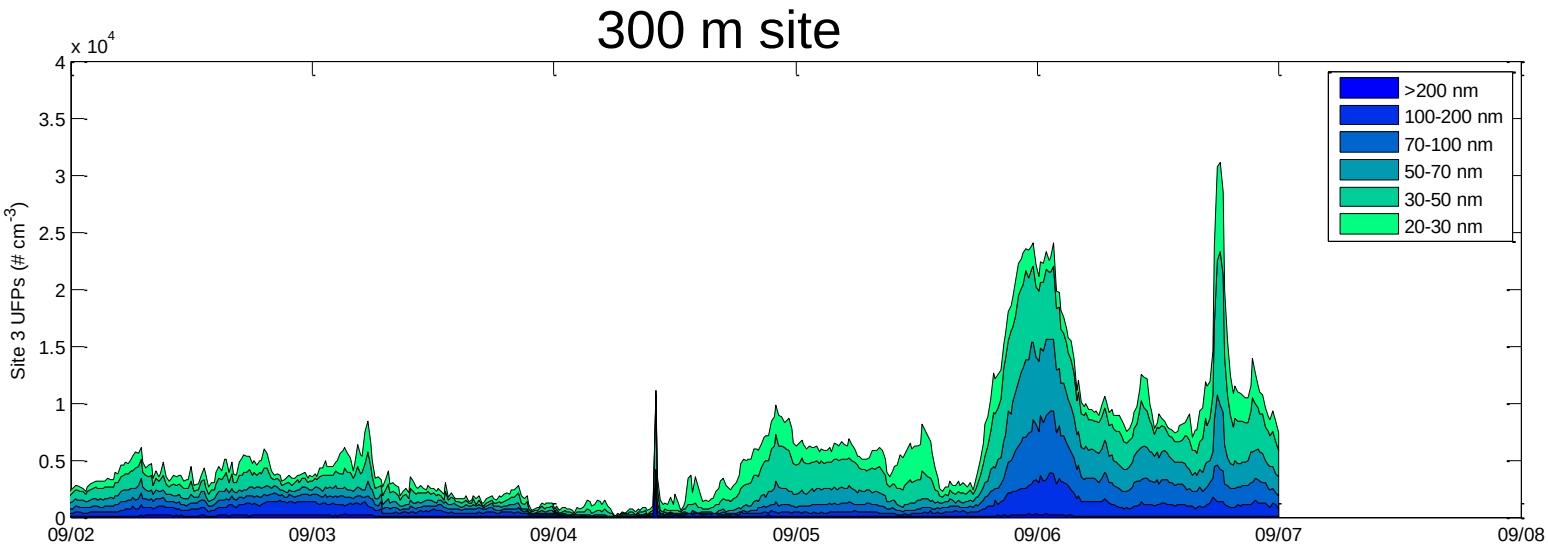
- Some issues of (minor) concern
  - Some issues with firmware (interface freezing, difficult changing timestamp) – recently updated to most current firmware and no complaints.
  - We found an educated eye needed to detect a measurement issue – instrument did not automatically detect problem. Area of general concern. (more to come)

Comments on instrumentation

Detroit example

Roadside and 300 m site have particles >100 nm tracking closely





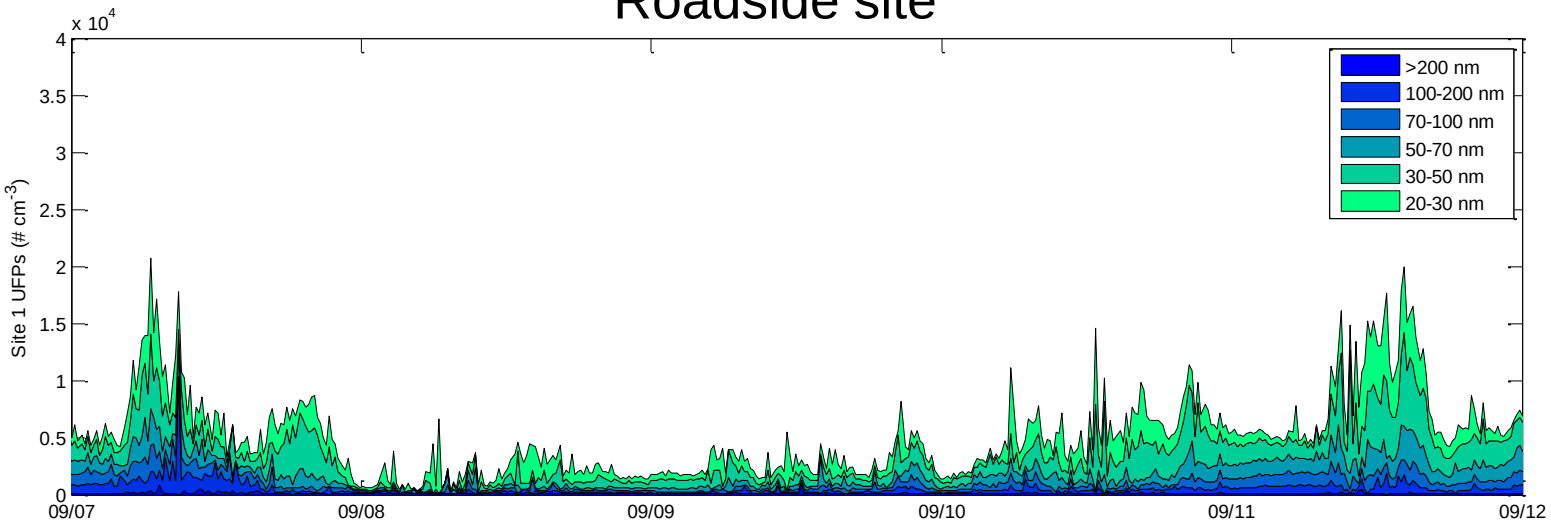
Comments on instrumentation

Detroit example

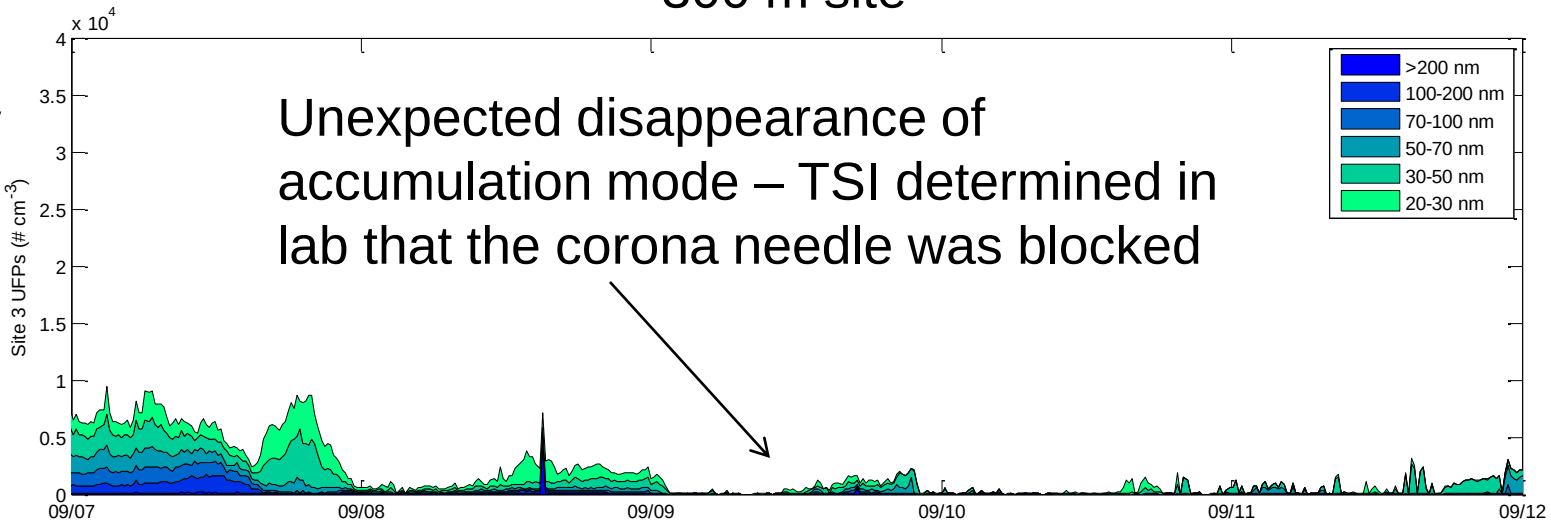
One week later…

No auto-reporting of measurement error. Required on-the-fly analysis by users to detect error.

Roadside site



300 m site

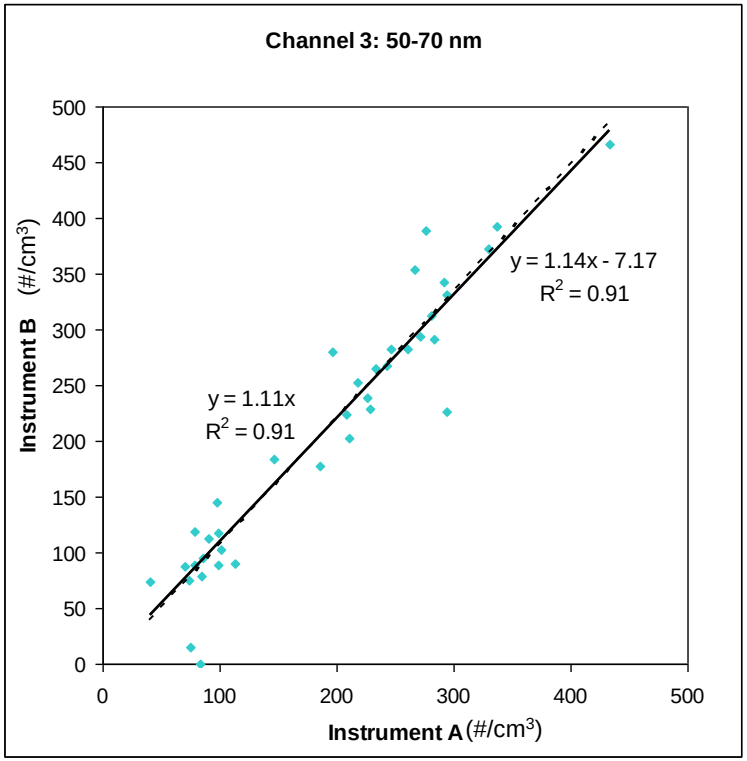


Intercomparison on instruments

Only had a brief opportunity to compare side-by-side, indoor levels in Las Vegas and Detroit

Longer-term ambient intercomparison ongoing at a site in Durham, NC.

e.g., Las Vegas

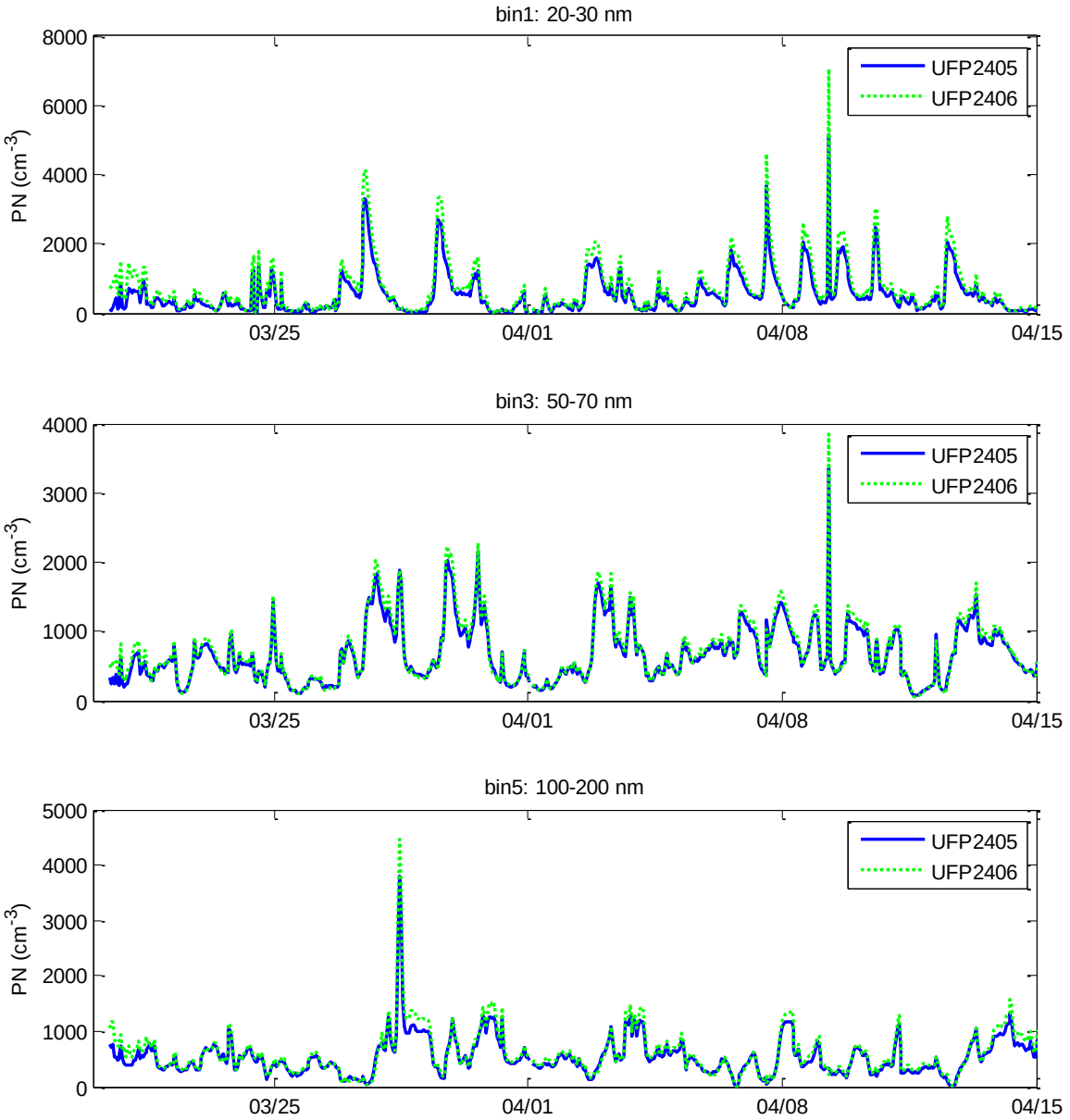


Intercomparison on instruments

Ambient monitoring site on EPA-RTP campus

Intercomparison on instruments

1 month of data (March-April, 2012); hourly average



Intercomparison on instruments

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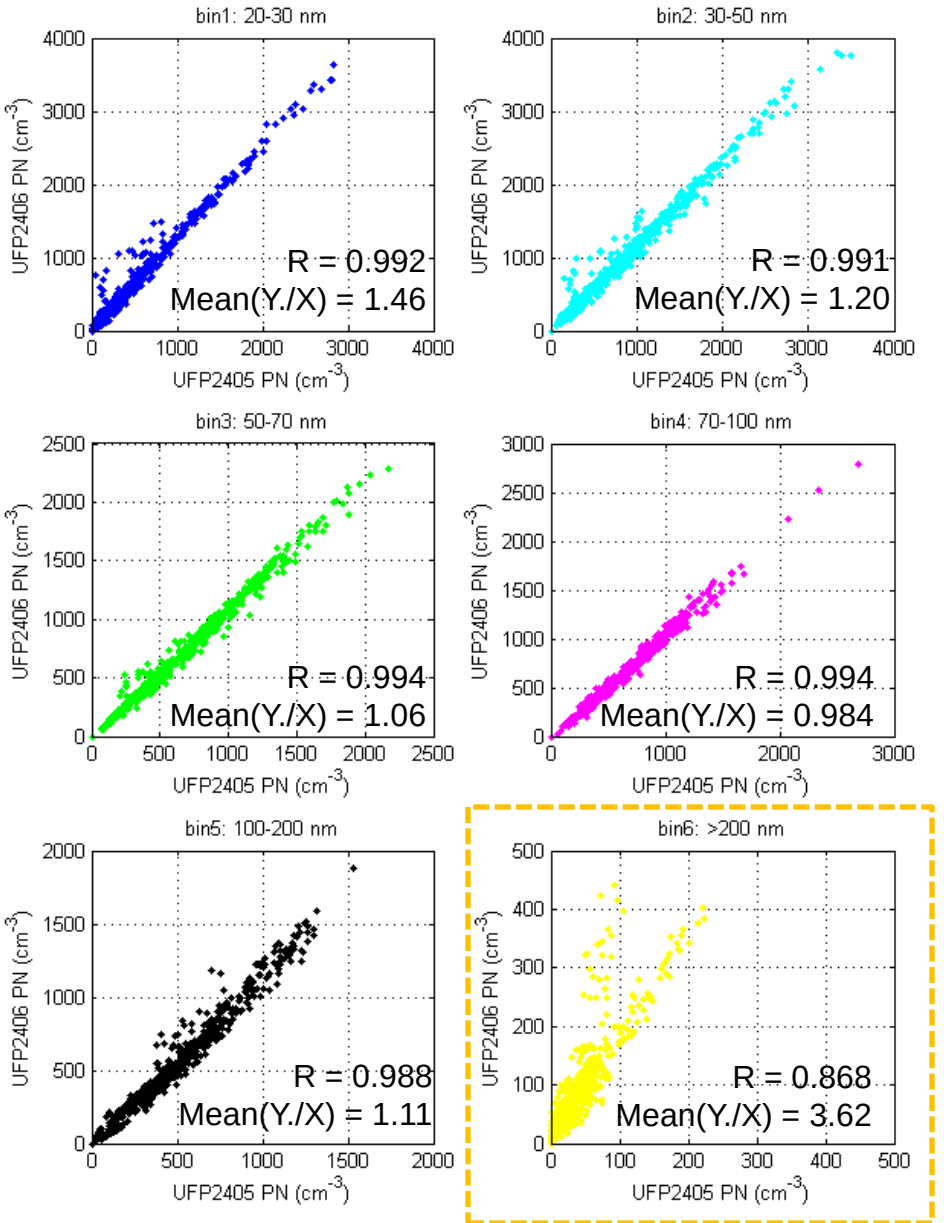


Near-road measurements

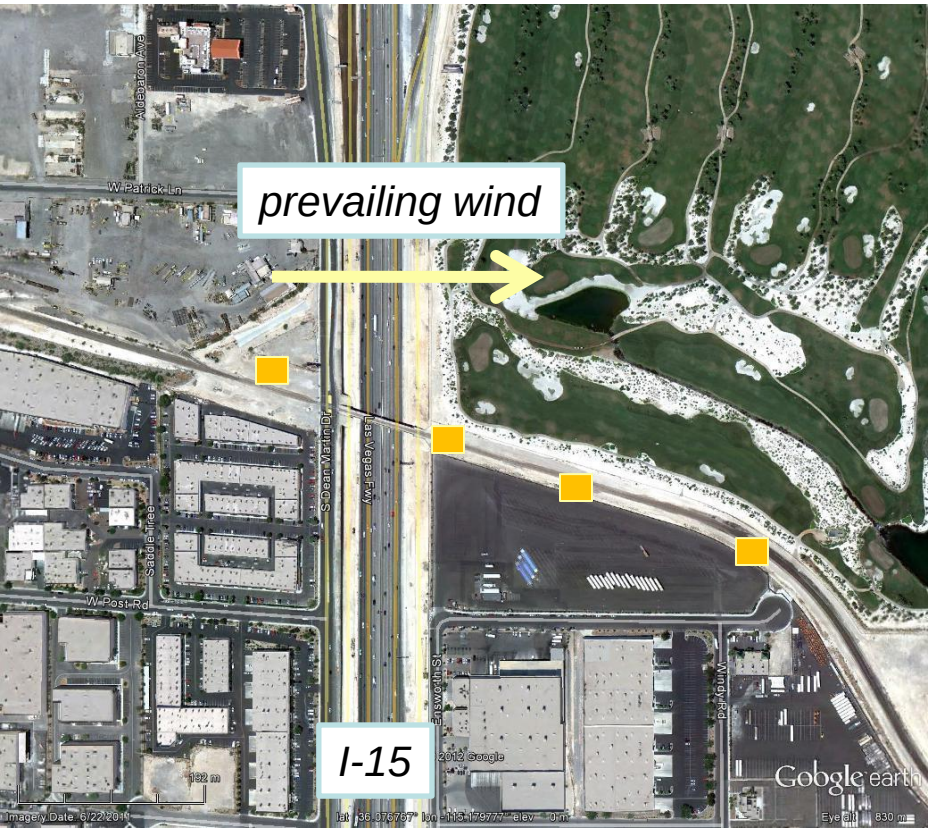
- EPA implemented two ~1 year near-road monitoring studies, through an interagency agreement with FHWA.
  - Las Vegas: 2009-2010
  - Detroit: 2010-2011

- Measurements at 4 distances from a major highway
  - Prevailing downwind side: roadside (#1),100 m (#2), 300 m (#3)
  - Upwind station (#4)

- Measurements included:
  - Gas phase: CO, $NO/NO_2/NOx$, air toxics (canisters, cartridges)
  - Particle phase: $PM_{2.5}$, black carbon, ultrafine particles
  - Additional: meteorology, traffic volume

Field sites

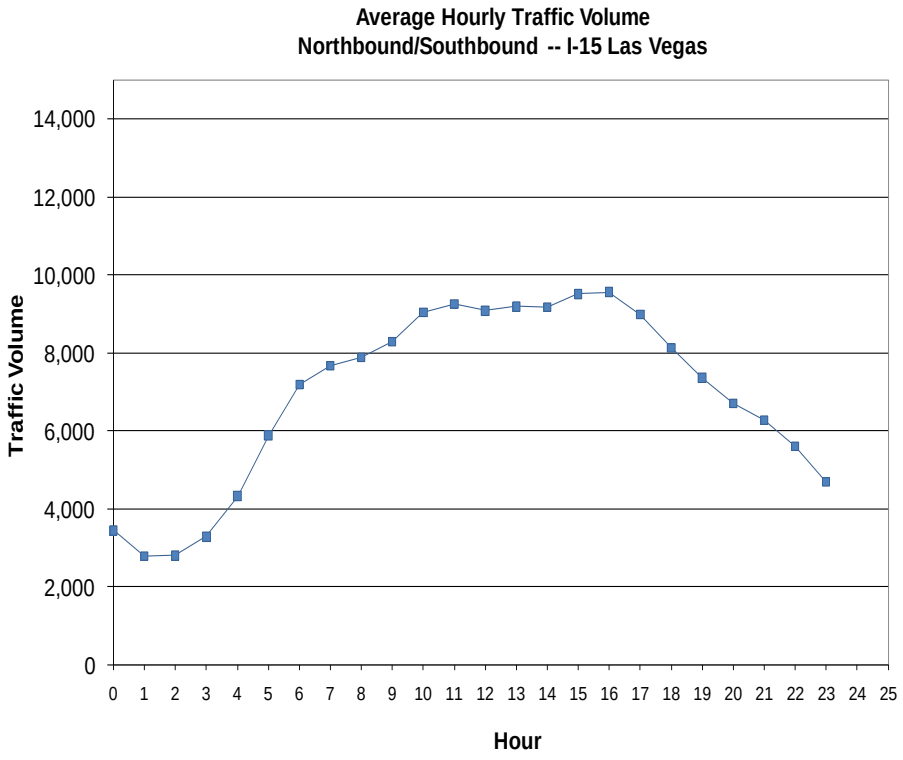
Las Vegas



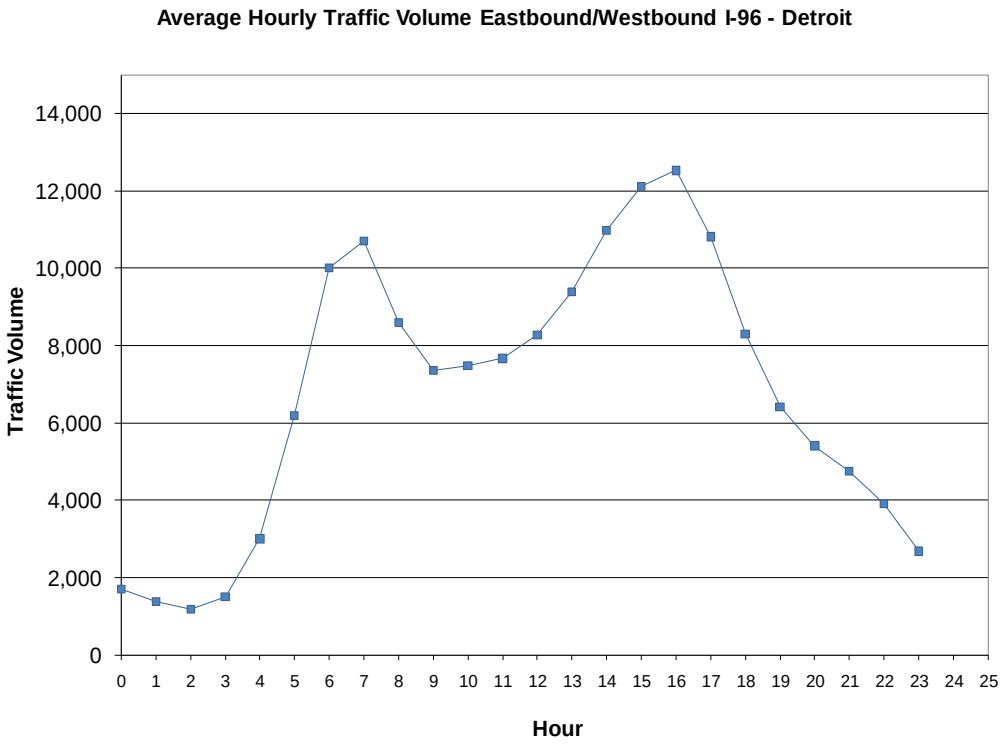
Detroit

Field sites – Traffic trends

Las Vegas



Detroit

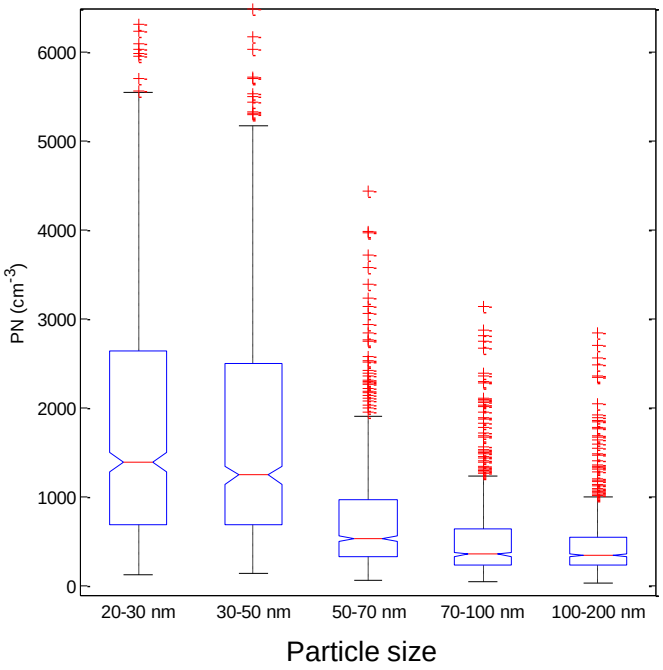


Las Vegas did not have typical biomodal diurnal trend – different trend likely due to operating hours of local industry, NAFTA corridor

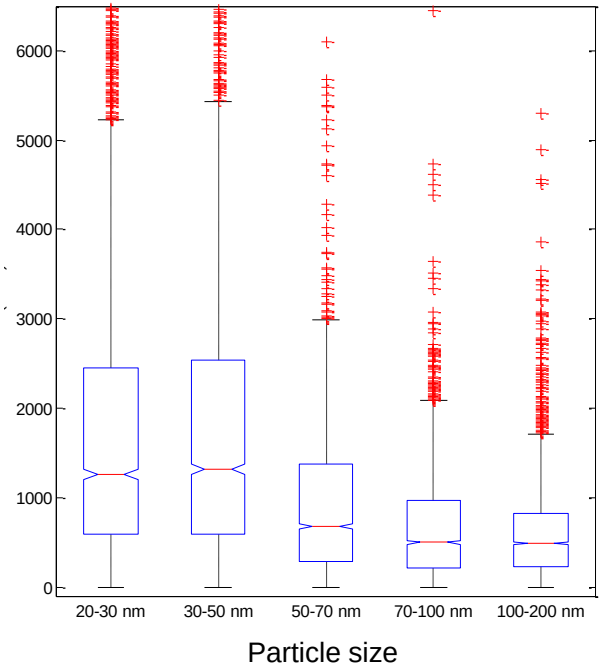
Concentration comparisons

One month comparison: March-April: LV (2010), Detroit (2011), RTP (2012)

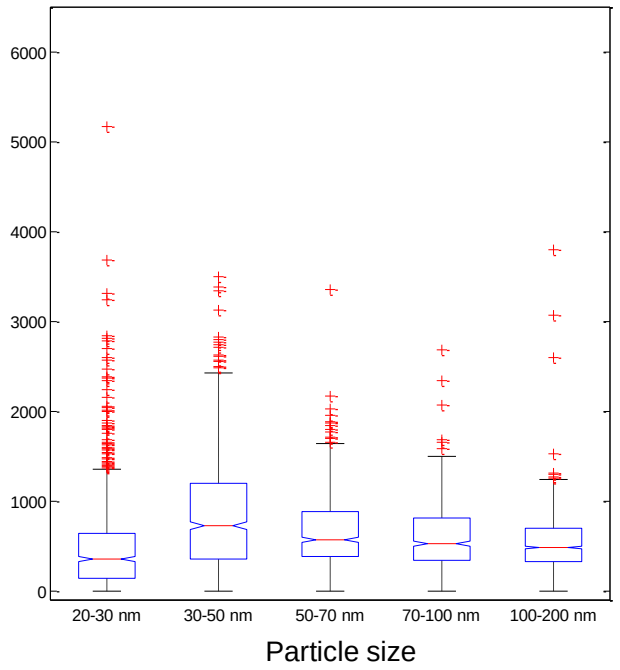
Las Vegas (20 m from road)



Detroit (<10 m from road)



RTP (ambient)



Long-term trends - monthly

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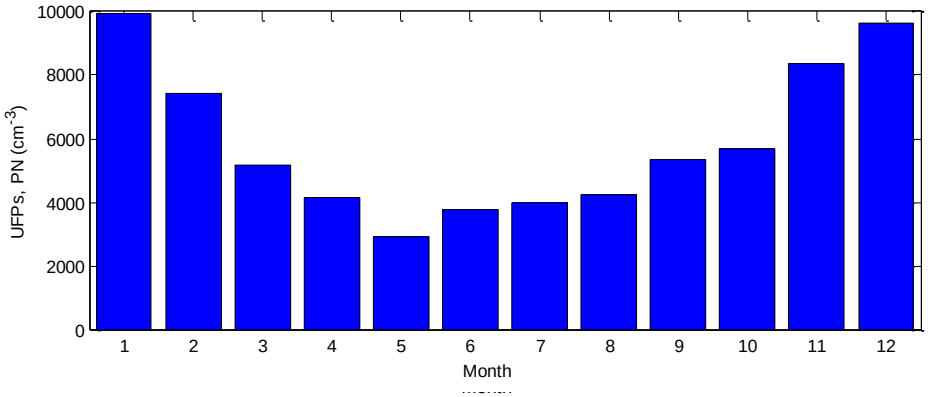
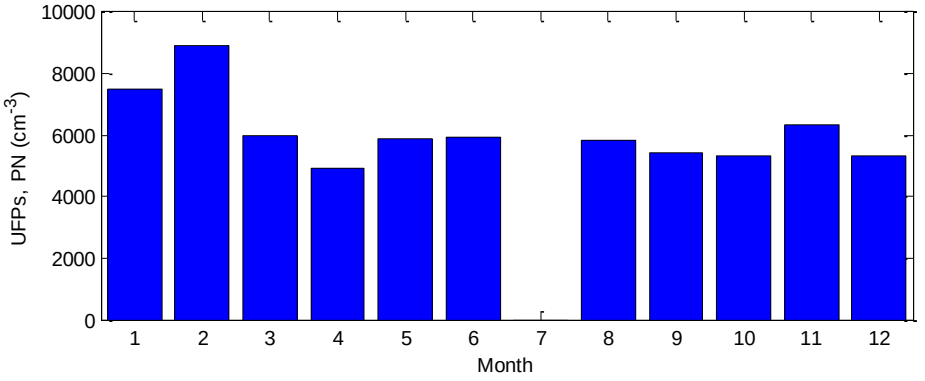
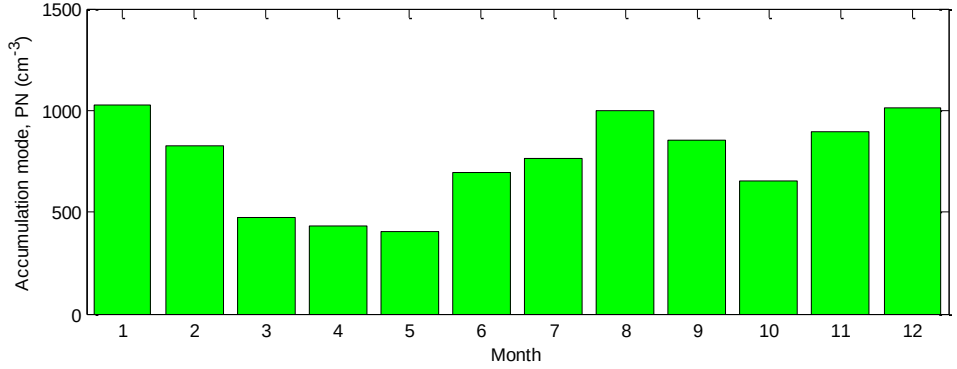
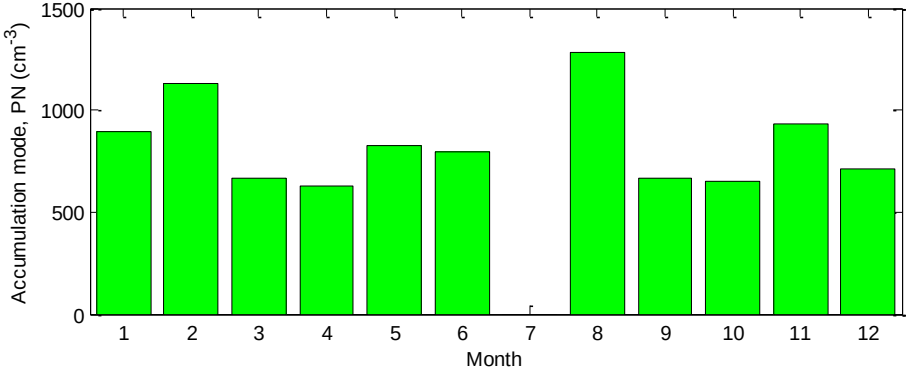
Las Vegas (roadside)



Detroit (roadside)





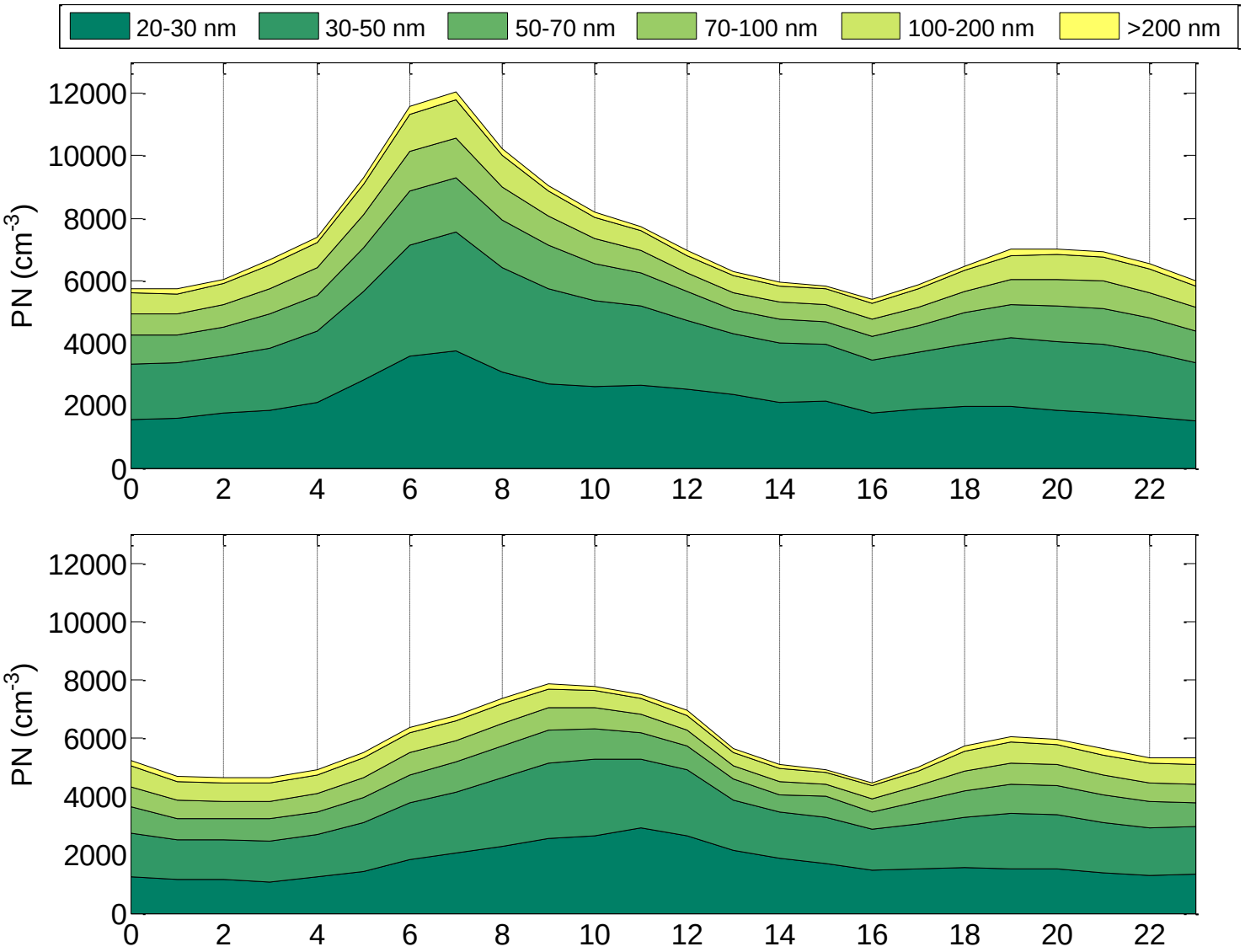


Long-term trends - diurnal

Las Vegas (roadside)

weekday

weekend

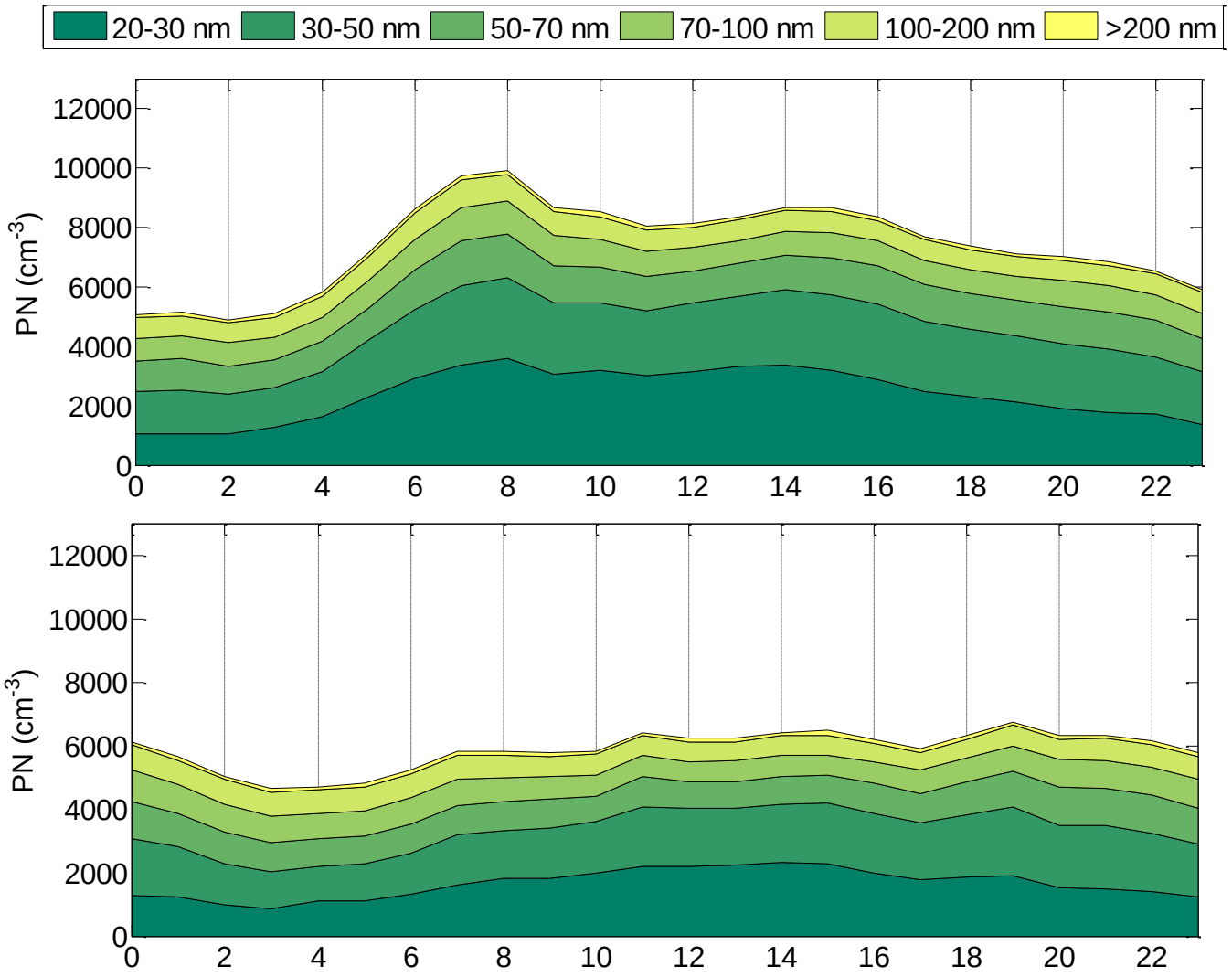


Long-term trends - diurnal

Detroit (roadside)

weekday

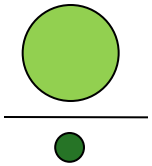
weekend



Exploratory data analysis

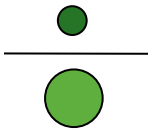
Q: Given a lengthy time series of 15 min particle count data, what trends can we extract?

Strategy 1: Assess ratios between bins:



Bin 5: 100-200 nm particles

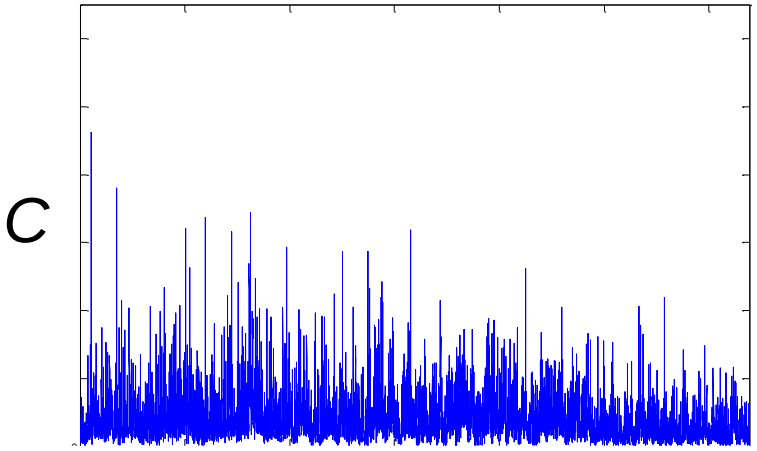
Bin 1: 20-30 nm particles



Bin 1: 20-30 nm particles

Bin 3: 50-70 nm particles

Strategy 2: Look at frequency decomposition of signal



Frequency analysis, separation into slow-varying and fast-varying signals

Strategy 1: bin ratio analysis

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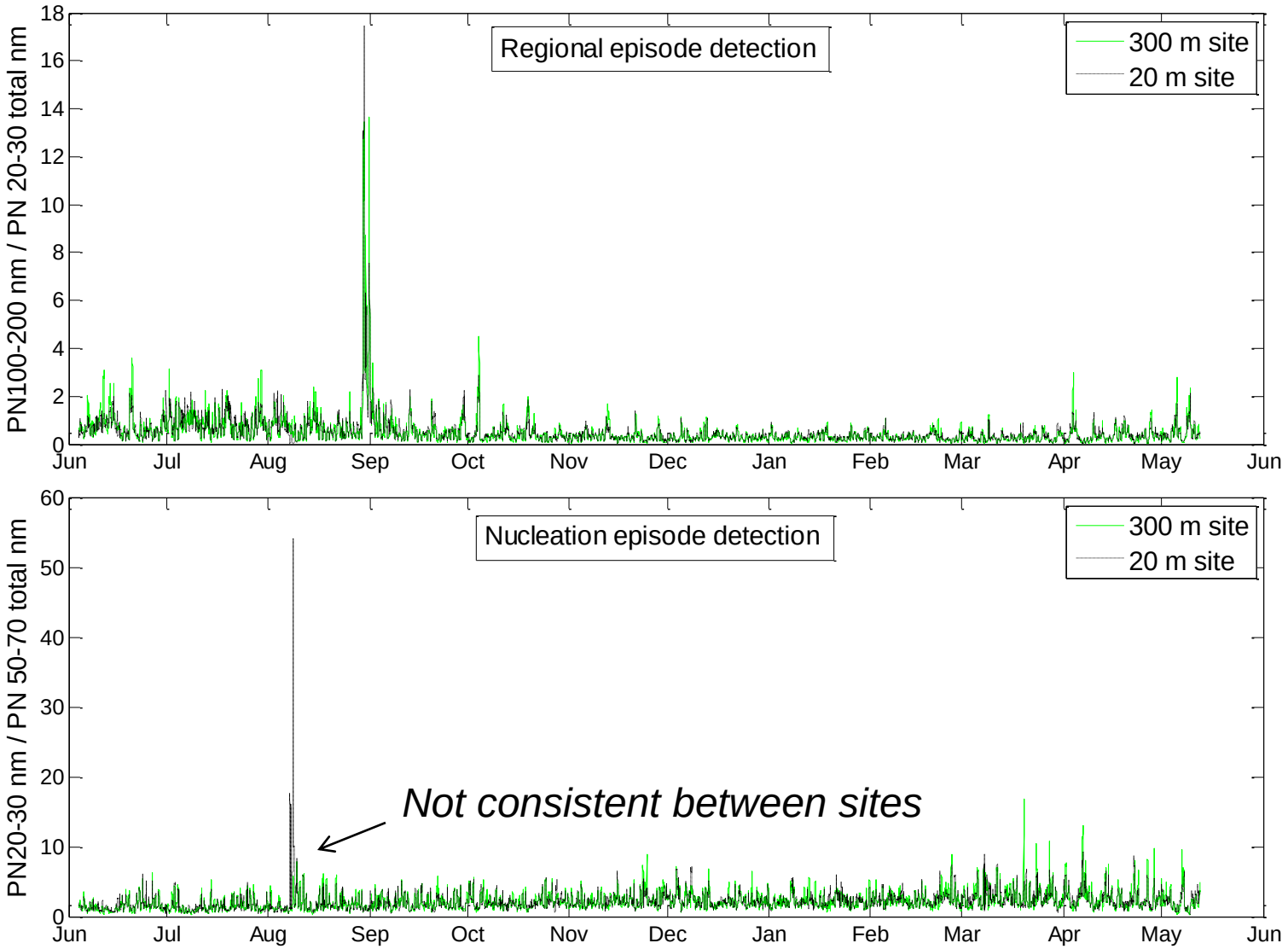
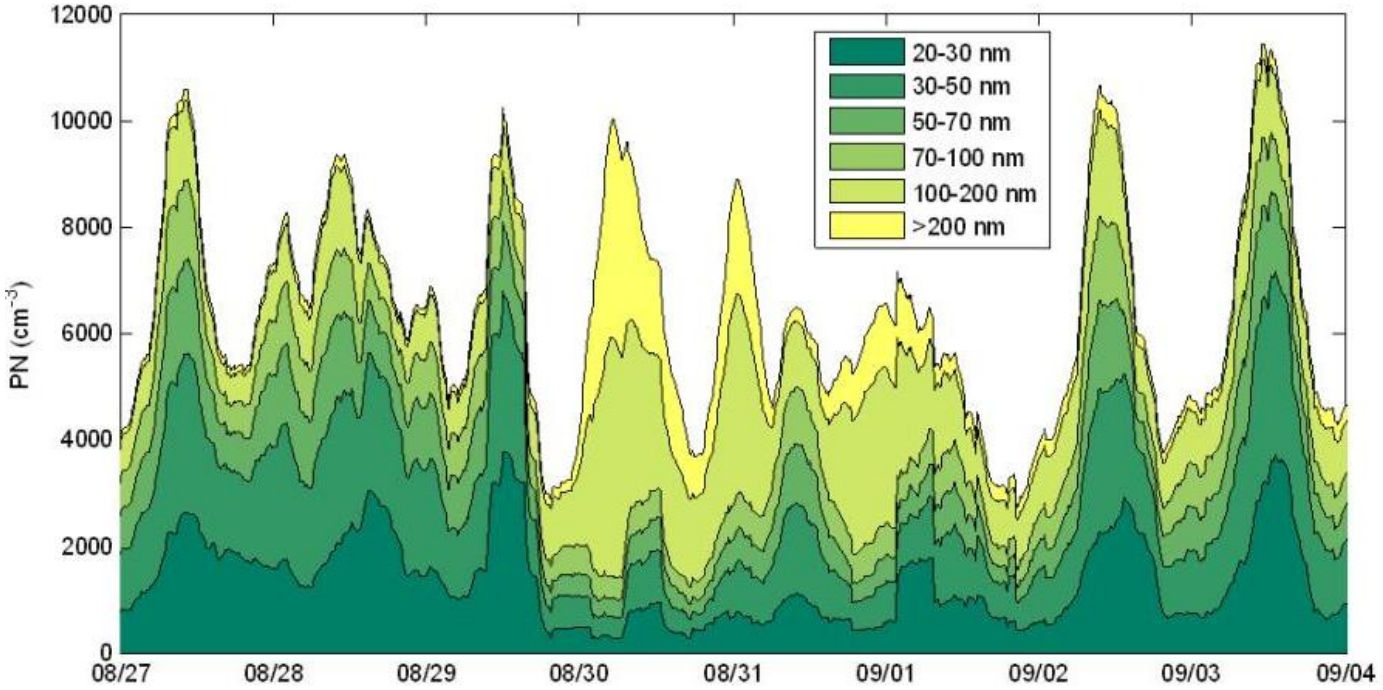
Bin-ratio based detection of unique episodes



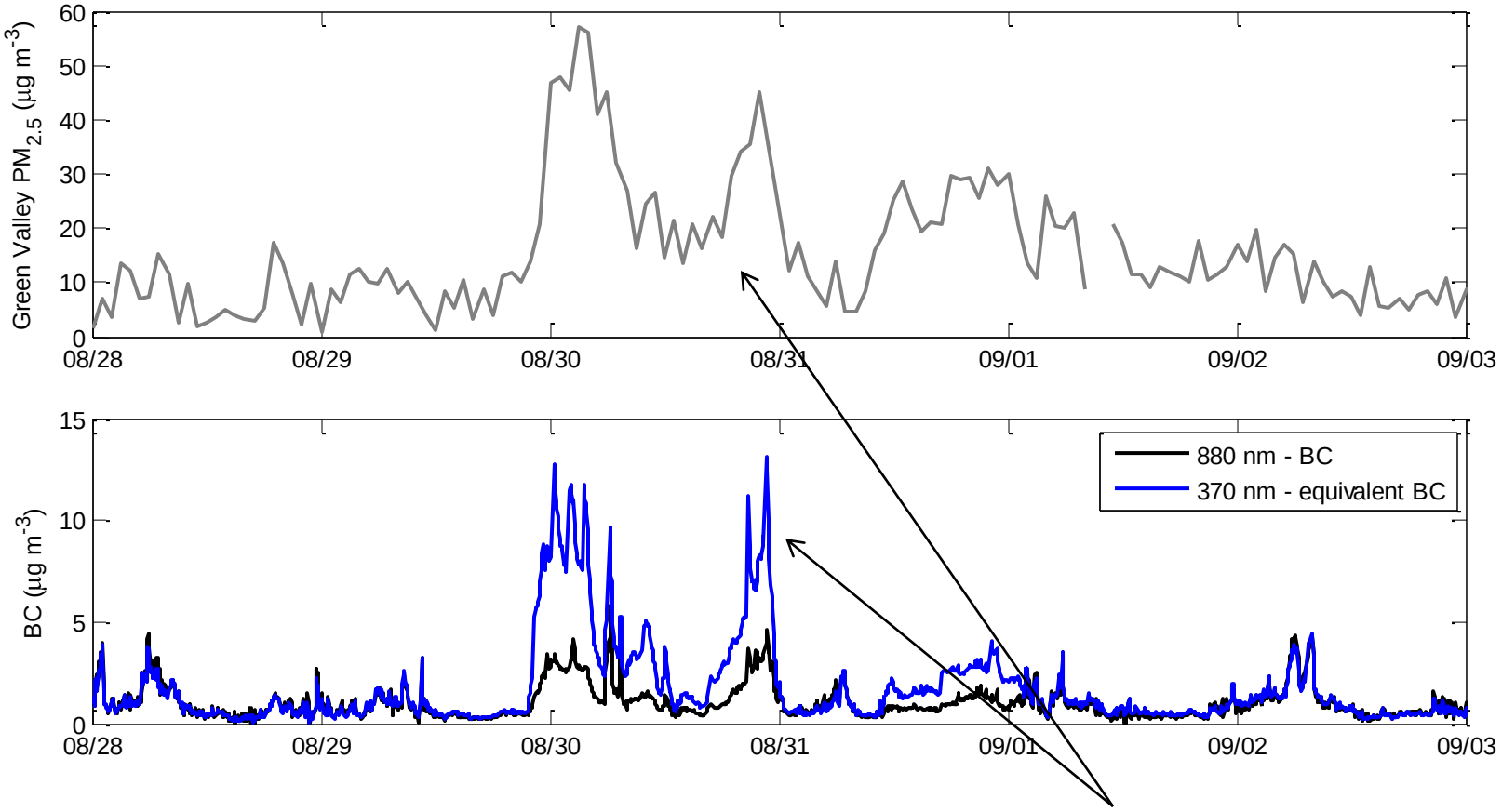
Bin ratio: accumulation mode event

Las Vegas: Aug 30-Sept 1



Bin ratio: accumulation mode event

"Accumulation mode event"

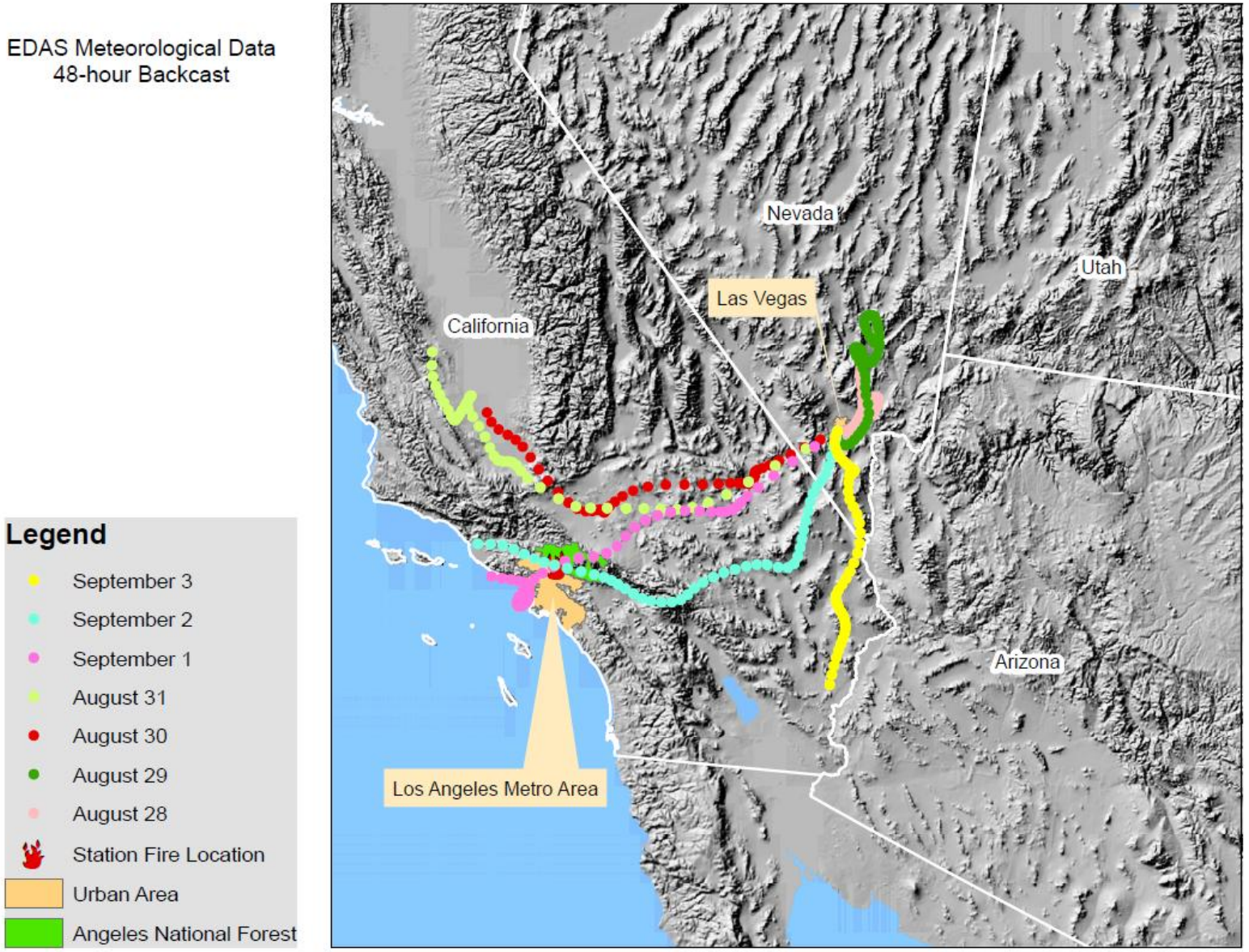


Corresponding increase in regional $PM_{2.5}$ and UV-absorbing particles

Bin ratio: accumulation mode event

Back-trajectory analysis via Hysplit

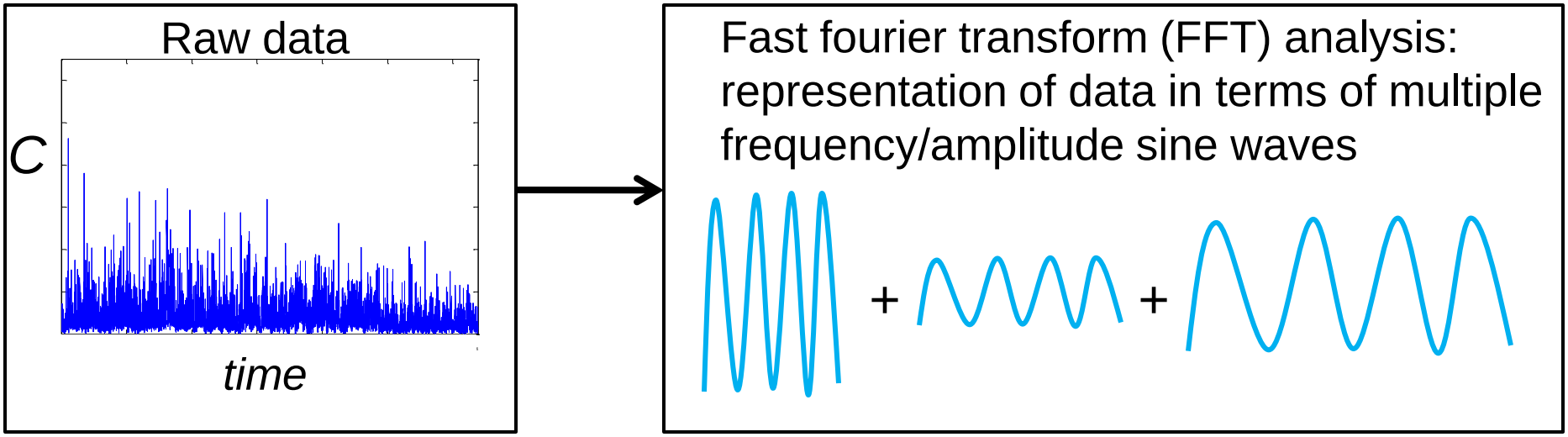
(Kimbrough et al.)



Strategy 2: Signal decomposition

Goal: separation of signal into fast-varying and slow-varying components…assumption that fast = local event driven, slow = regional event driven.

Step 1:



Strategy 2: Signal decomposition

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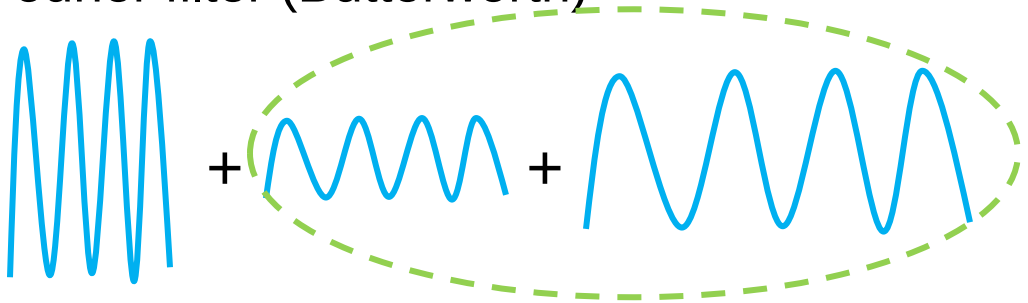
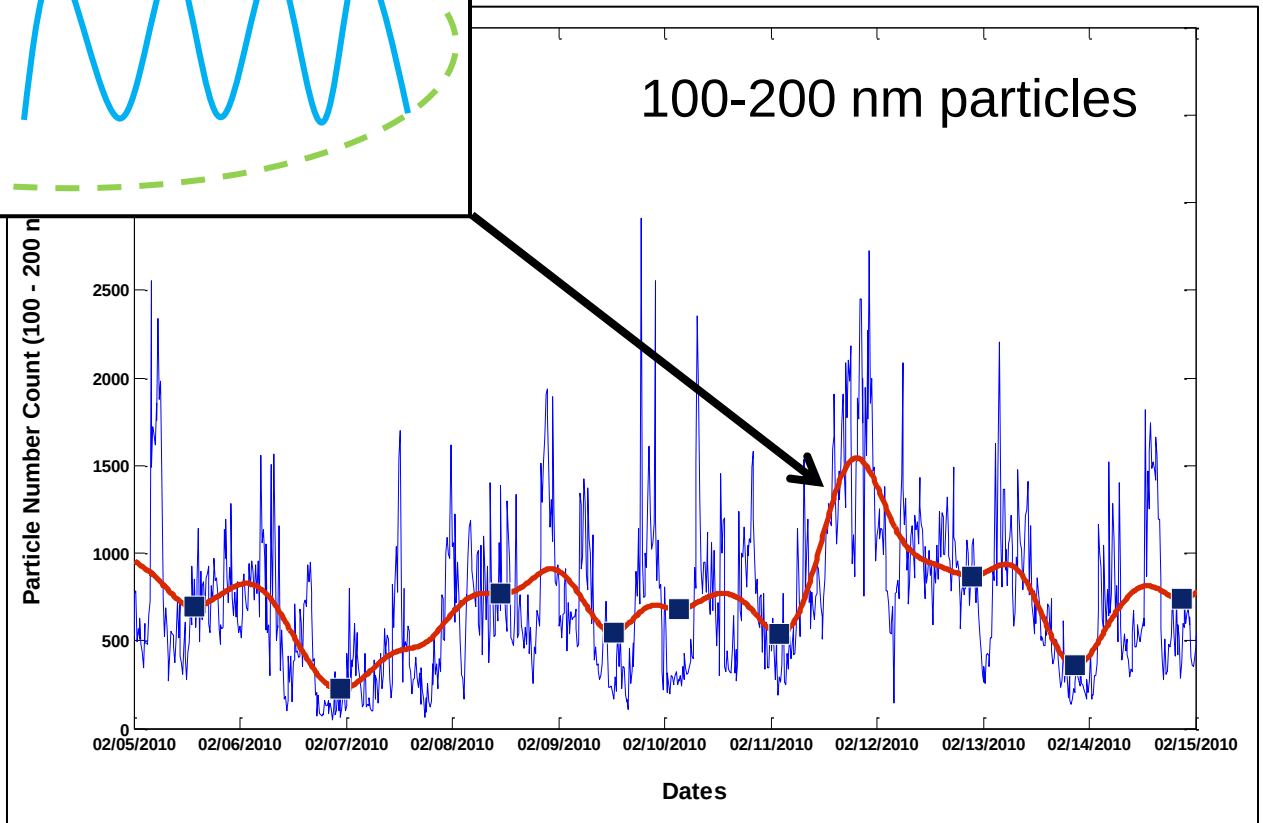
Step 2:

Isolation of slow-varying components to estimate “regional” contribution through Fourier filter (Butterworth)



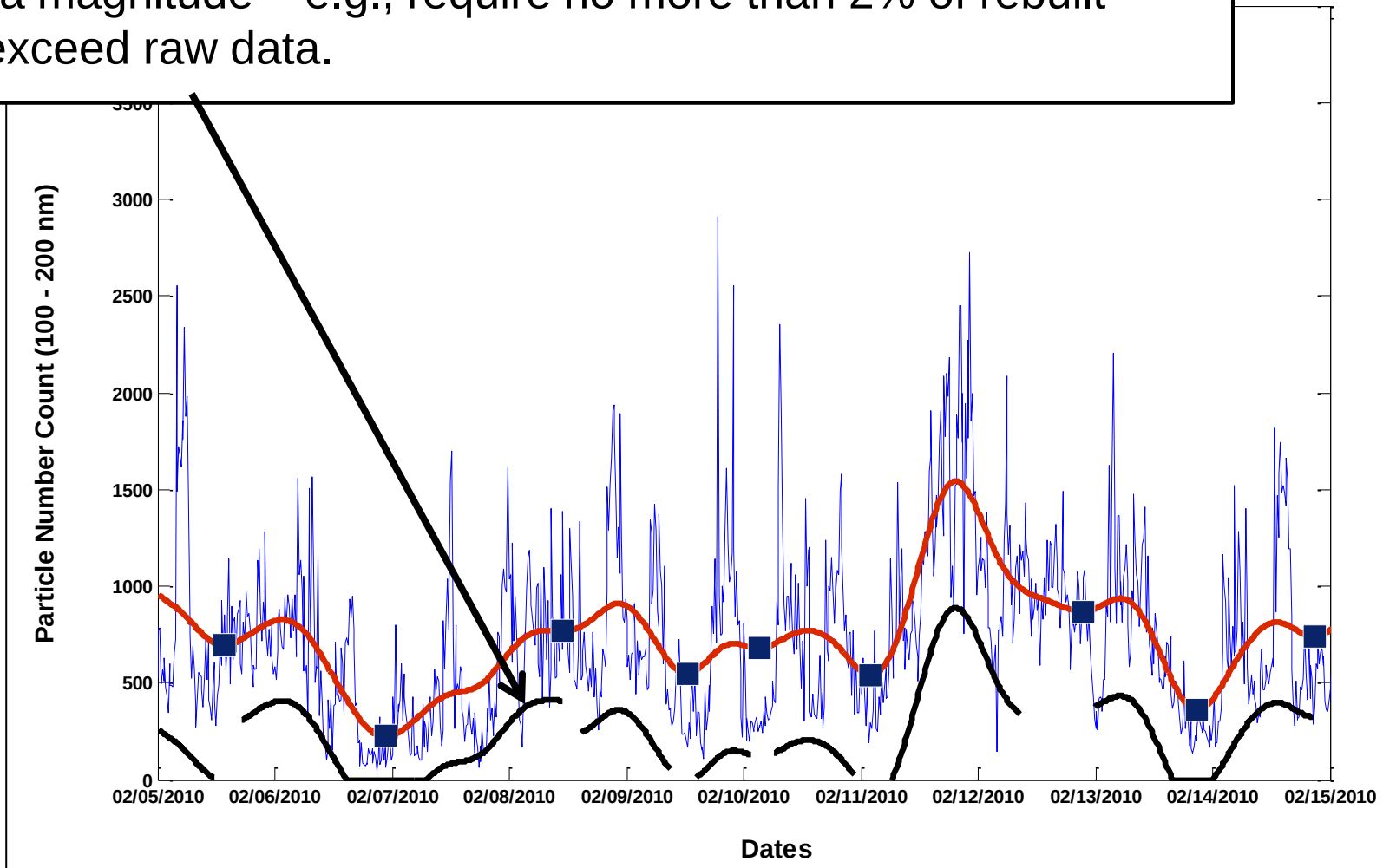
Problem: Subtracting the “non-local” (red) from the original signal produces “local” contributions that are negative.



Strategy 2: Signal decomposition

Step 3:

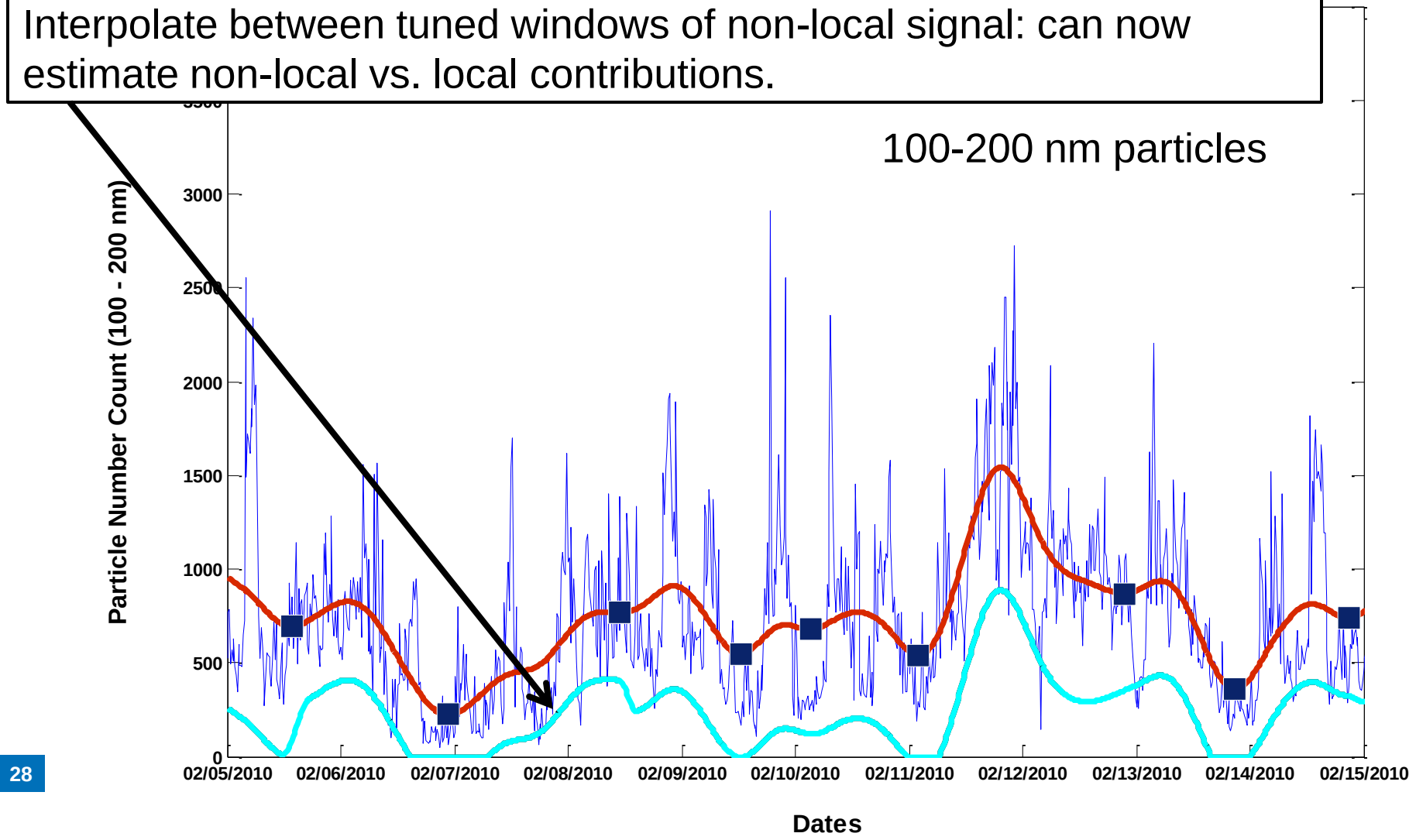
Tune rebuilt “non-local” signal in discrete windows to remain below raw data magnitude – e.g., require no more than 2% of rebuilt signal exceed raw data.



Strategy 2: frequency analysis

Step 4:

Interpolate between tuned windows of non-local signal: can now estimate non-local vs. local contributions.



Summary

- Instrument intercomparison and performance
  - Some concern about lack of flagging of data for case where corona charger not functioning properly.
  - High correlation between instruments for bins 1-5, poor agreement for bin 6 (>200 nm).
- Trends:
  - Similar size-resolved concentrations at Detroit and Las Vegas for example 1-month period – signal dominated by <50 nm particles. RTP ambient environment has lower concentrations and more even size-resolved concentrations from 20-200 nm.
  - Both Detroit and Las Vegas exhibit bimodal diurnal trend on weekdays, however, timing of afternoon “bump” much later in LV relative to Detroit.
- Exploratory data analysis:
  - Bin ratio method successful in detecting significant regional event.
  - Signal processing approach under development.

Acknowledgements

TSI – Jeff Baker, loan of two 3031 monitors for Las Vegas study, continuing support during Detroit / RTP work.

EPA Near-Road Team involved in UFP sampling implementation – Bill Mitchell, Carry Croghan, Bill Squier, Rich Baldauf, Carlos Nunez, Dan Costa

Federal Highway Association (FHWA)

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